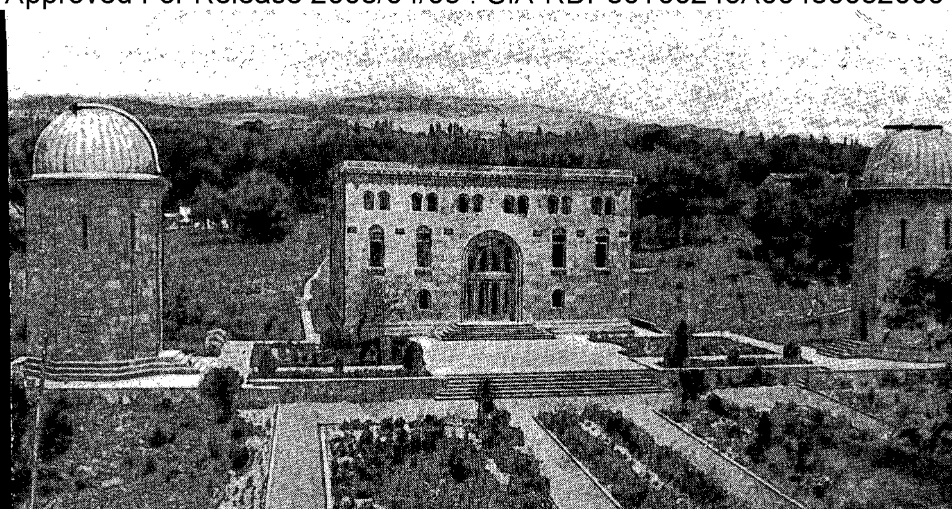

L. V. MIRZOYAN

# THE BURAKAN ASTROPHYSICAL OBSERVATORY

1958

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ACADEMY OF SCIENCES OF THE USSR
ACADEMY OF SCIENCES OF THE ARMENIAN SSR

L. V. MIRZOYAN

# THE BURAKAN ASTROPHYSICAL OBSERVATORY

1958

ON THE OCCASION OF THE X GENERAL ASSEMBLY OF
THE INTERNATIONAL ASTRONOMICAL UNION, MOSCOW

*12—20 August 1958*

*Edited by*
P. G. KULIKOVSKY

The Burakan Astrophysical Observatory of the Academy of Sciences of the Armenian SSR, is one of the yóungest in the Soviet Union (fig. 1). Its construction was begun in 1946. This was the time when the scientific activity of the Observatory has commenced.

The past ten years have witnessed the completion of the first part of the construction, the installation of several instruments, the organization of scientific laboratories and the consolidation of the scientific staff. Papers written by the members of the Observatory staff are being published in the «Communications of the Burakan Observatory», issued since 1946, and in other publications of the Academies of Sciences of the USSR and the Armenian SSR. The main works carried out at the Observatory were of great value for astronomy and attracted the attention of scientists in different countries.

A brief description of the Burakan Astrophysical Observatory and some of the scientific results are given below.

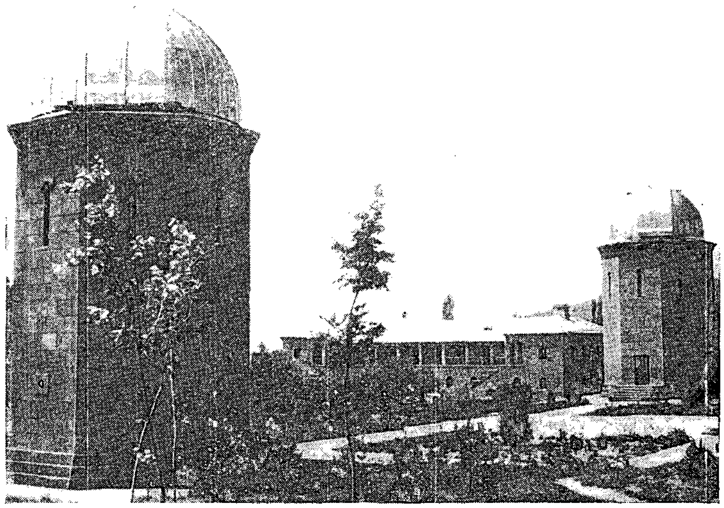

Fig. 1. The Burakan Astrophysical Observatory. The domes and the hotel

## CONSTRUCTION OF THE OBSERVATORY AND THE INSTALLATION OF INSTRUMENTS

An astronomical observatory, mainly for educational purposes, was established at the Erevan State University in 1933—1934. Some scientific observations of the Sun, meteorites and variable stars, as well as works on the history of astronomy in Armenia were being dealt with. A 9-inch visual telescope, which belonged to the Leningrad University, was the only instrument of the Observatory. The telescope was equipped with two cameras and was employed for photographic observations.

In May 1940, after the incorporation with the Armenian branch of the Academy of Sciences of the USSR, Professor V. A. Ambartsumian was appointed scientific adviser

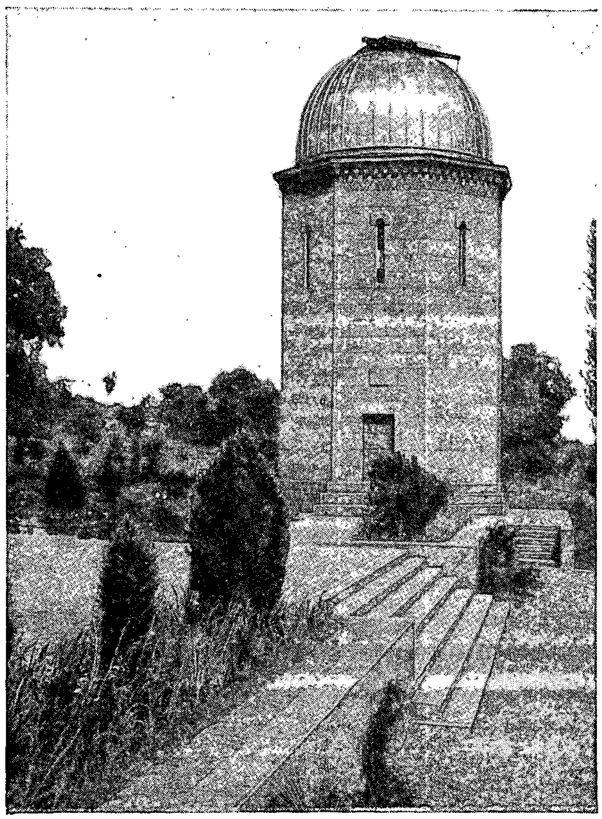

**Fig. 2.** The dome of the 8-12-inch Schmidt telescope

Under the supervision of V. A. Ambartsumian the Observatory has studied mainly astrophysics. In connection with this the construction of a new astrophysical observatory outside the city with atmospheric conditions favourable for astrophysical observations became indispensable. Such a site was found near the Burakan village (1500 m above sea level, $2^h57^m10^s$ E and 40°20′7″ N). The construction



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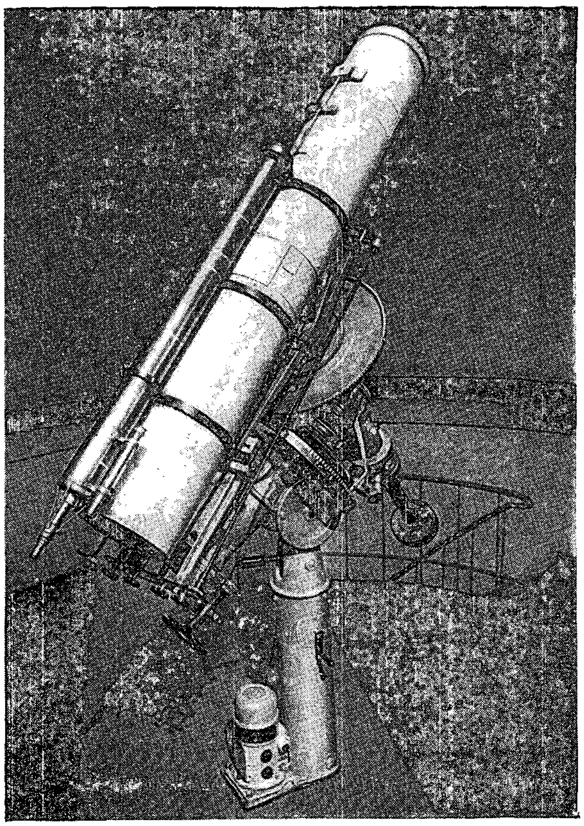

Fig. 3. 8-12-inch Schmidt telescope

at the site was begun in 1946. At the same time the training of young armenian scientists was underway.

The first telescope installed in Burakan in 1946 was a 5-inch double astrograph with «Ernostar» objectives ($f=240$ mm) and with an effective field of approximately 300 square degrees. It was used for two-colour photographic observations of variable stars. In 1948 a 8-12-inch Schmidt telescope ($f = 1.0$ m) was assembled and mounted, and photographic observations of selected Milky Way areas for statistical star-counts were started (fig. 2 and 3).

Two new instruments were mounted in 1949: a 10-inch telescope (fig. 4) with aspectrograph designed by O. A. Melnikov and B. K. Ioannissiani, and a nebular spectrograph (fig. 5). The focal ratio of the telescope-spectrograph is 3 : 1. The diameters of the parabolic mirrors, the foci of which coincide, are 250 and 40 mm respectively. The Cornu quartz prism (E = 60°) in the second parallel beam permits observations of the ultraviolet regions of stellar spectra. The nebular spectrograph is used for spectral of diffuse nebulae. It was designed by Ioannissiani and the optical parts were manufactured under the supervision of D. D. Maksutov. The distance between the «slit» and the camera is 50 m. The length of the mirror «slit» is 70 cm and its width can be changed up to 30 cm. The diameter of the camera mirror is 150 mm, the focal length 150 mm. The dispersion of light is achieved by means of two prisms with a 30° refracting angle.

Astrophysical observations were practically begun after the installation of the 8-12-inch Schmidt camera and the two spectrographs, mentioned above. This enabled the research of stellar associations discovered at the Burakan Observatory in 1947.

This discovery was an outstanding event in the life of the Observatory, and subsequently directed its activity to the study of associations, as well as stars and nebulae connected with them.

A 16-inch telescope (fig. 6) with an electrophotometer in the Cassegrain focus was installed in 1950 for colometric and polarimetric observations of stars and nebulae.

In 1952 a 6-inch double astrograph (fig. 7) with Zeiss

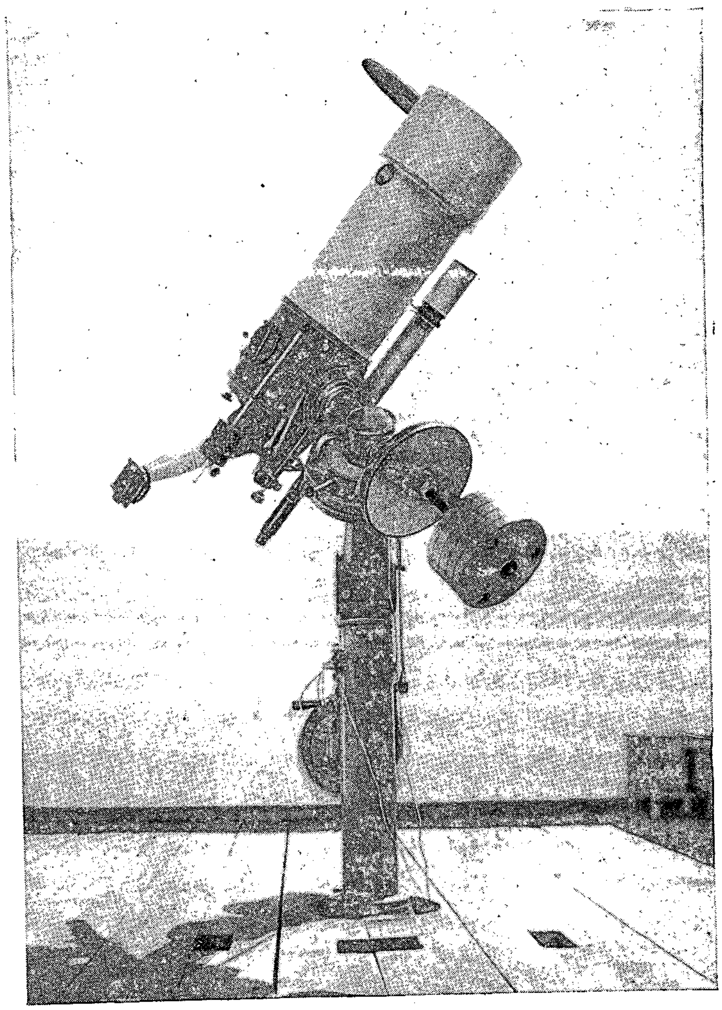

Fig. 4. 10-inch telescope-spectrograph

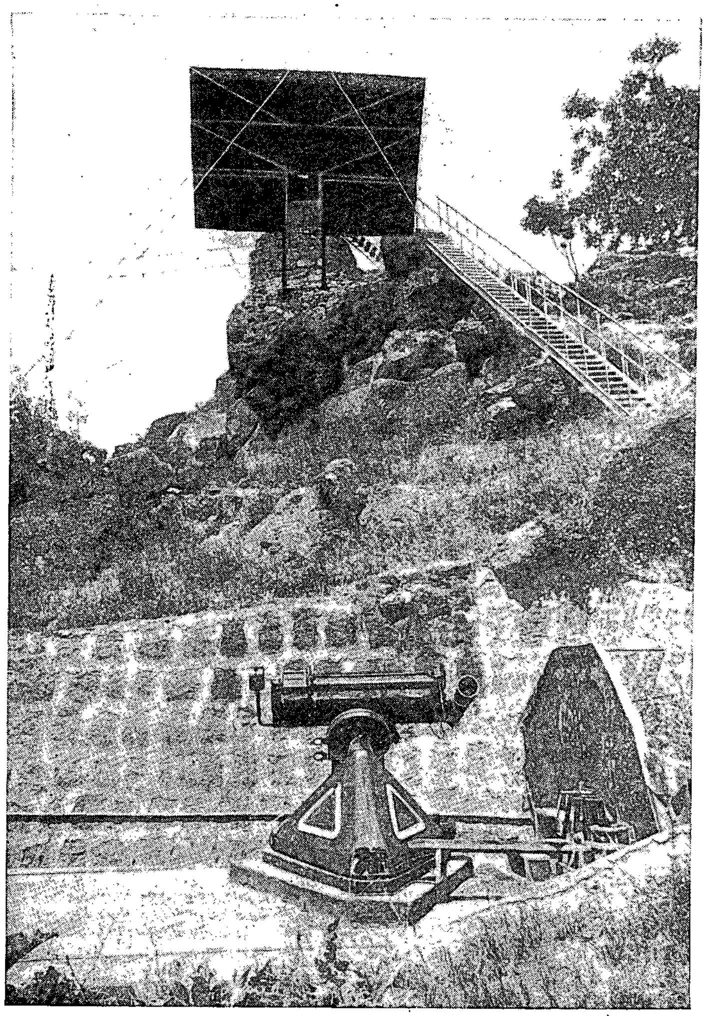

Fig. 5. Nebular spectrograph

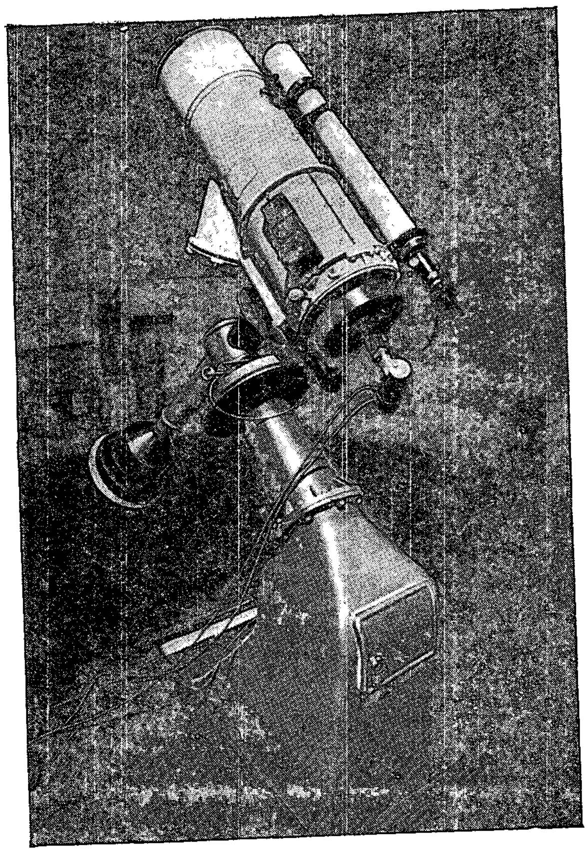

Fig. 6. 16-inch coma-free telescope

objectives ($f_1 = 1.0$; $f_2 = 1.5$ m) was assembled at the Observatory shop. This astrograph is used for two-colour photographic observations of variable stars. A Schmidt telescope with a mirror and a correcting lense having equal diameters (21-inch, $f = 1.8$ m) (fig. 8 and 9) was mounted in Burakan in 1954 and colorimetric observations of galaxies were begun.

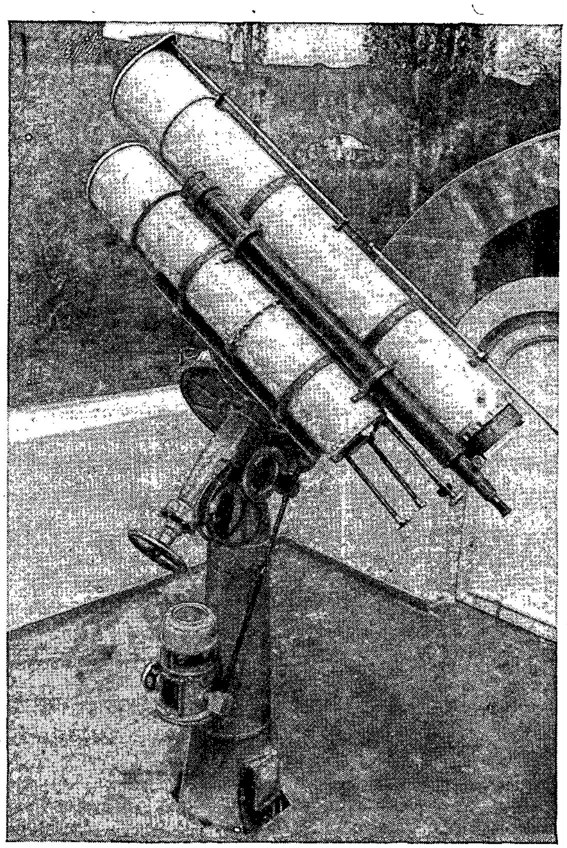

Fig. 7. 6-inch double-astrograph

The designing and construction of radio telescopes had commenced at the Observatory in 1950. As early as 1951 the radio emission of the Sun was observed by means of a radio telescope with a 3 m parabolic mirror on 50 cm wavelength.

In 1951—1952 a radio telescope with a flat synphase aerial responding to the 4.2 m wavelength was built for

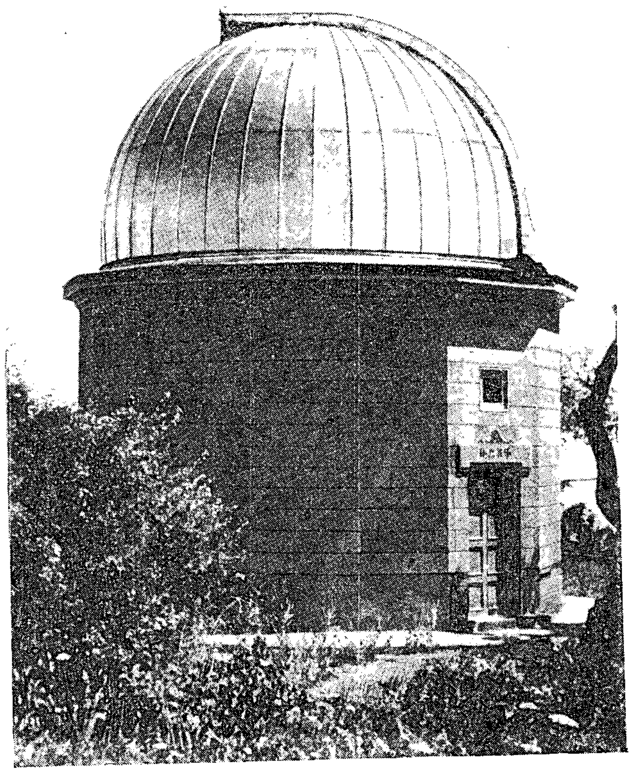

Fig. 8. The dome of the 21-inch Schmidt telescope

observations of the discrete sources of cosmic radio emission (fig. 10). The installation of a second similar aerial made the application of the interference method possible.

In 1953—1955 two new flat synphase aerials were constructed for the interference radio telescope responding to the 1.5 m wavelength (fig. 11). All the receivers and aerials of the radio telescopes were made at the Observatory. Since 1955 radio astronomical observations of the discrete sour-

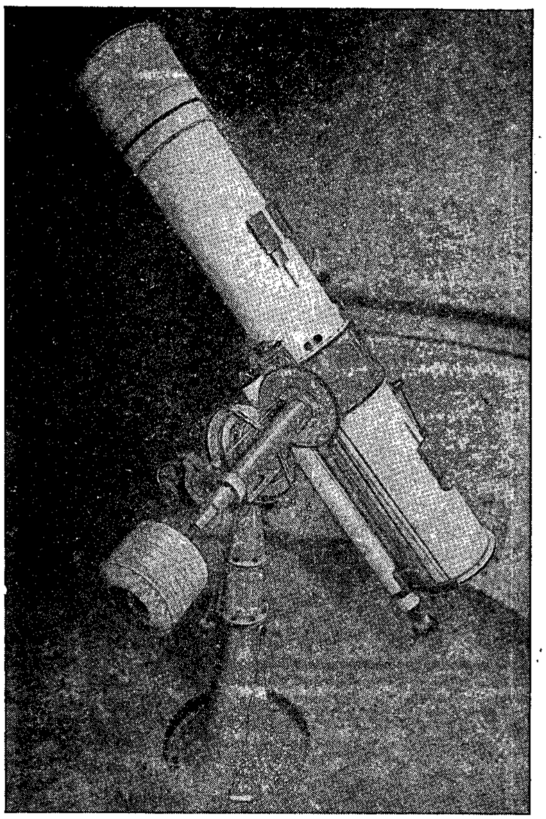

Fig. 9. 21-inch Schmidt telescope

ces in the centimeter wavelength range are being conducted.

A large amount of construction work was carried out. The main laboratory building with a conference-hall, studies and laboratories of the departments of stellar astronomy and physics of stars and nebulae, a library and the office were completed by September 1951. Instrument designing and construction laboratory, a number of towers and pavilions for observations, a hotel (fig. 12), a temporary laboratory of radio astronomy, living houses and offices were completed later. All the buildings of the Burakan Observatory are erected from the local rose felsite in a traditional Armenian style, after the architectural design by Prof. S. A. Safarian (fig. 13).

The inauguration of the Observatory took place on September 19, 1956, in the presence of numerous soviet and foreign astronomers. A conference on unstable stars was dedicated to this event, where over 50 scientists from six countries (China, France, Mexico, USA, USSR, Yougoslavia) participated.

The construction of the second part of the Observatory is now underway. A radio astronomy station in Saravand (at a higher altitude than Burakan) and new living houses are being built. Works connected with the building of a dome for the large one-meter Schmidt telescope were commenced.

Graduates of the Erivan University constitute a considerable part of the Observatory staff. Since its formation the Observatory collaborates with other Soviet observatories and astronomical institutions and particularly with Pulkovo, the Leningrad University, the Crimean, Abastumani observatories and the Sternberg Astronomical Institute in Moscow.

## THE SCIENTIFIC ACTIVITY OF THE BURAKAN OBSERVATORY

The main task of the scientific research at the Observatory is the study of the composition of the Galaxy and closely allied problems on the origin and evolution of stars. A brief description of the investigations carried out at the Observatory is given below.

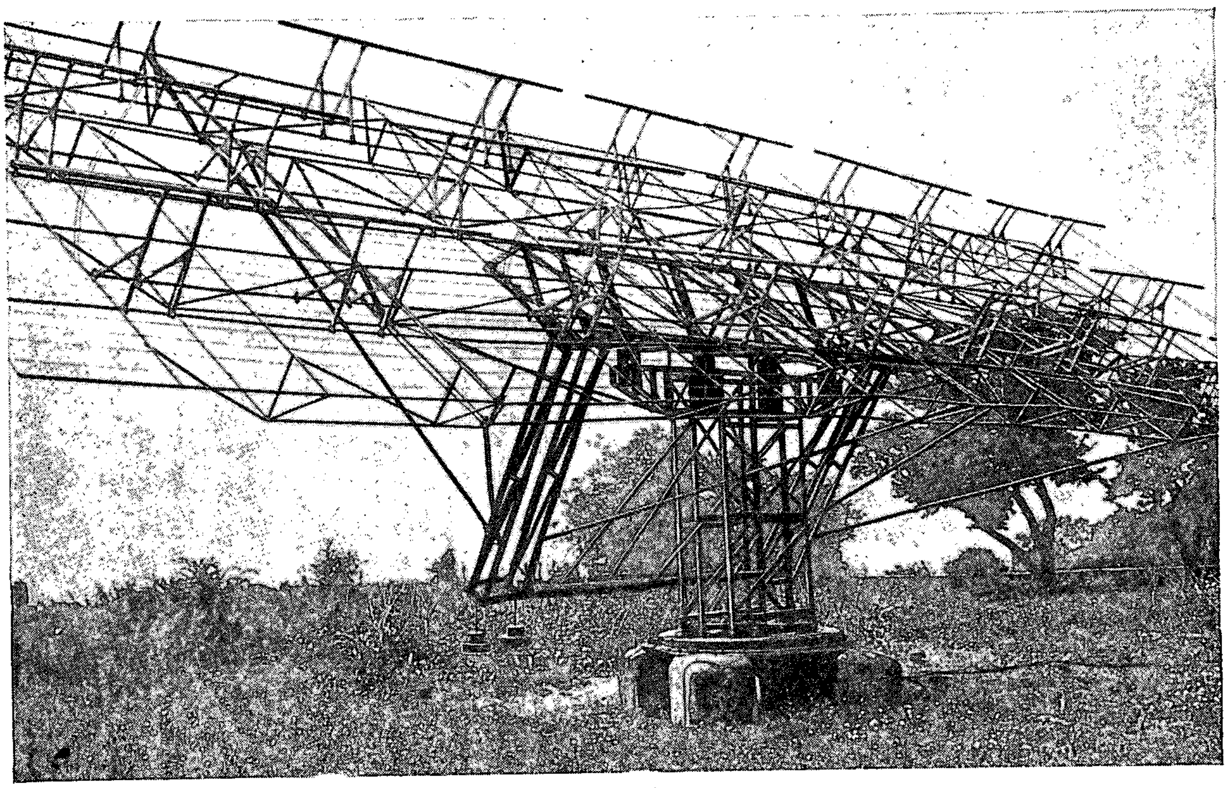

Fig. 10. One of the aerials of the 4.2 m radio interferometer

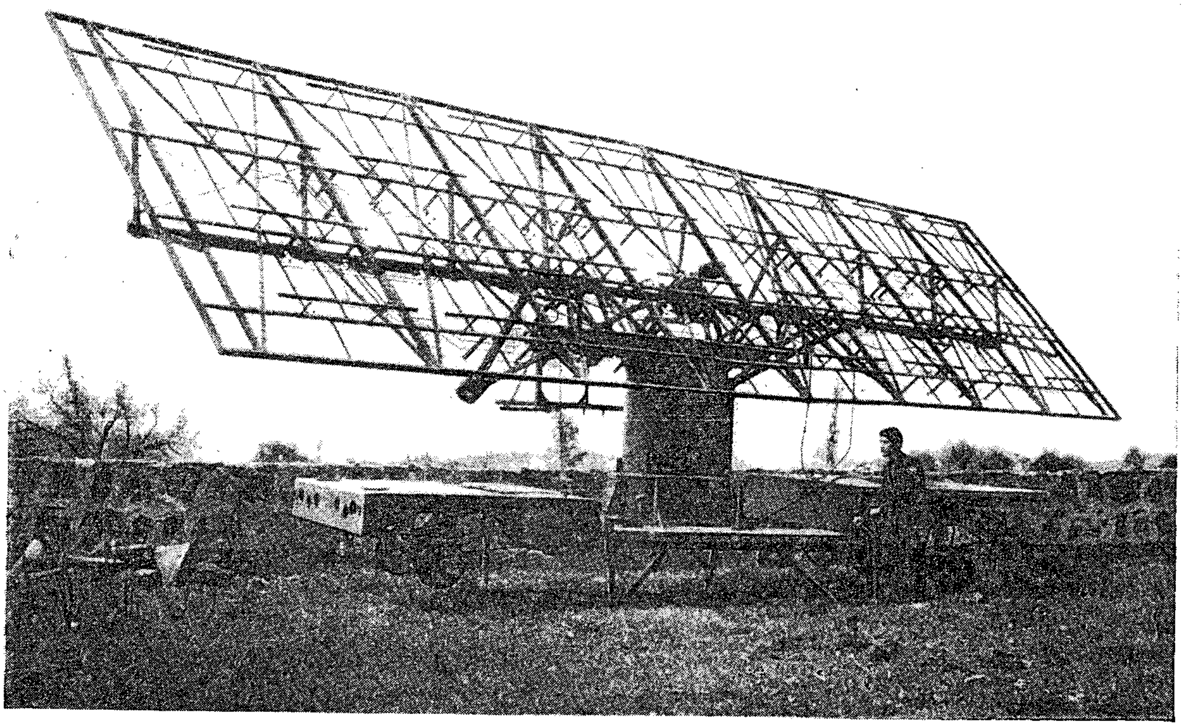

Fig. 11. One of the aerials of the 1.5 m radio interferometr

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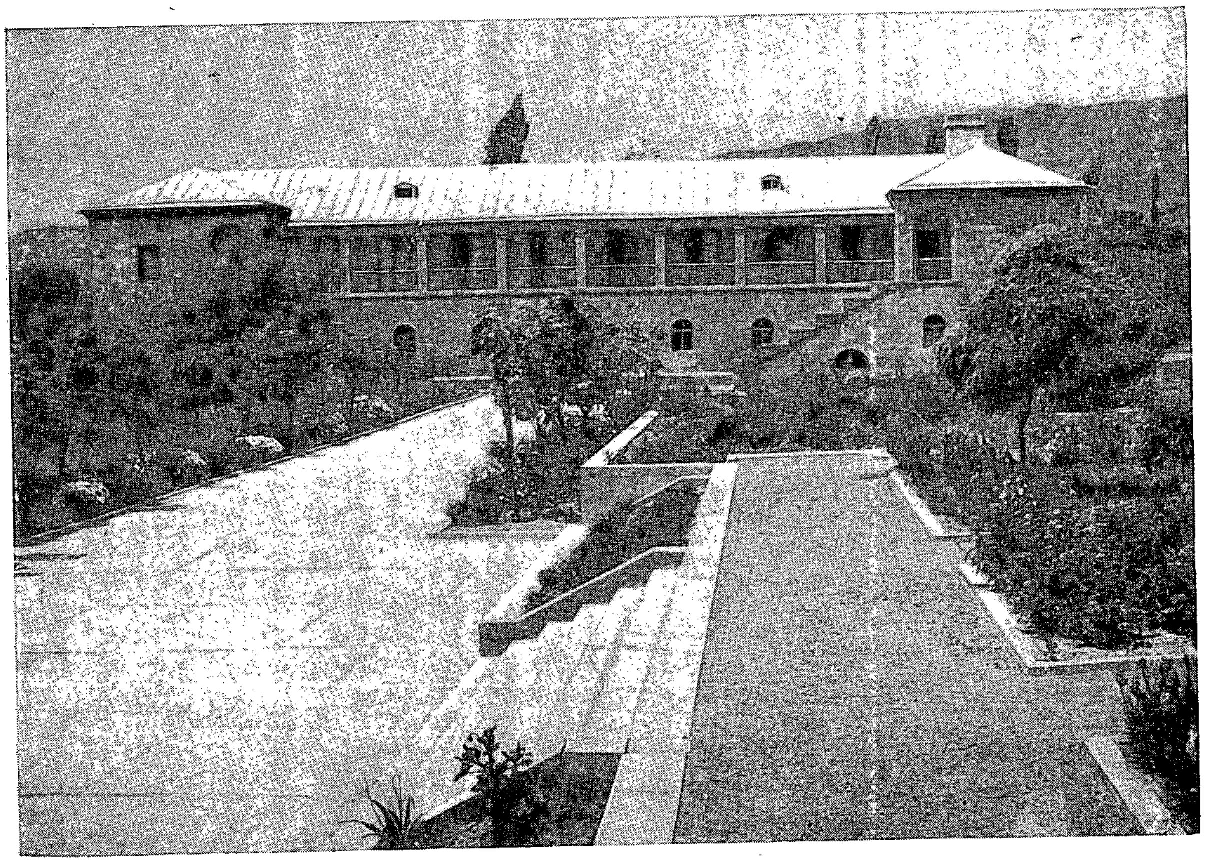

Fig. 12. The Hotel

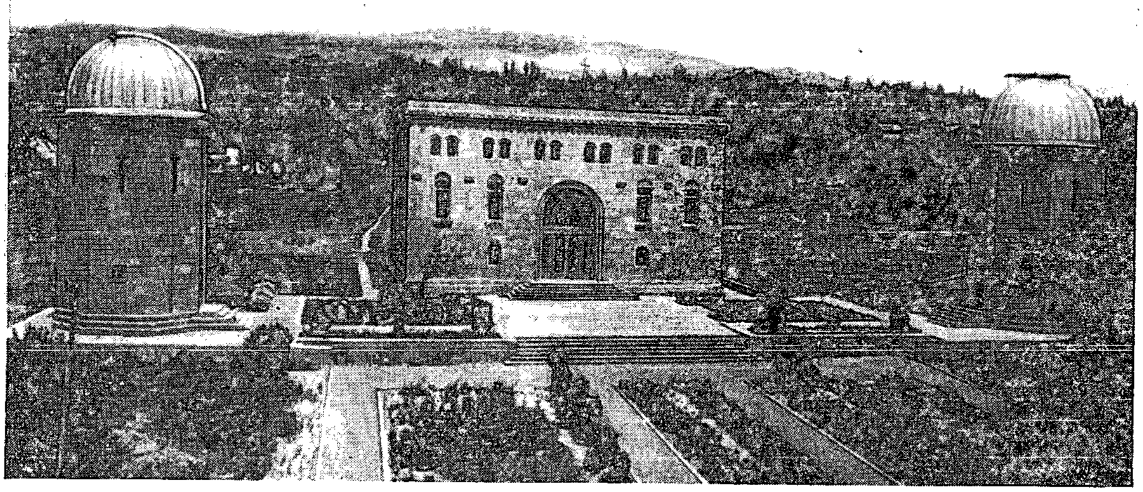

Fig. 13. The general view of the Observatory from the South

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## Statistical studies of stars and interstellar matter

When the cloud structure of the interstellar medium was established by V. A. Ambartsumian and Sh. G. Gordeladze (1938) statistical studies of the properties of absorbing clouds became necessary, the more so as they cannot be generally observed directly on account of their small optical thickness. A means for solving this problem was found in the theory of fluctuations of star numbers and the numbers of galaxies and also of the fluctuations of the brightness of the Milky Way, worked out at Burakan. It was shown that one of the most important factors causing fluctuations of the observed number of stars and galaxies is the fluctuation of light absorption due to the cloud structure of the interstellar matter. The mean optical thickness of the absorbing clouds was found to be 0.27.

The total absorption of light in the direction of the galactic poles, or the optical thickness of the absorbing layer of the Galaxy, was determined by the analysis of the apparent distribution of stars and their total brightness in high galactic latitudes.

A number of observational and statistical studies were devoted to interstellar light absorption in different directions, determination of the form of the Galaxy, the distribution of stellar and interstellar matter in it, etc.

Counts of stars of different brightness have shown that on the average stars are more concentrated near the central plane of the Galaxy than the interstellar absorbing matter.

Statistical studies of double and multiple stars and stellar chains lead to the conclusion that the components of each of these systems are of common origin. The possibility of formation of multiple systems as a result of the approach of separate stars ought to be completely excluded.

It was found that the probability of accidental arrangement of stars in multiple systems of the Orion Trapezium type* or in stellar chains was very low and that in most cases the observed multiple systems of the above type and stellar chains were unstable stellar groups in the Galaxy.

### Stellar associations and the origin of stars

Theoretical study of the space distribution of stars with different physical characteristics has resulted in the discovery in 1947 of stellar associations. This discovery was of the greatest importance for the development of our concepts of the origin and evolution of stars in spiral galaxies. This discovery and further studies of associations made the Burakan Observatory well known.

The density of stars in stellar associations is lower than in the general galactic field. But stellar associations are remarkable for the abundance of stars belonging to certain types. At present two types of associations are known: O-associations (containing hot giants of O and B types) and T-associations (of the T Tauri type variable stars).

Studies of the stellar association around the galactic cluster NGC 6231 have shown that the surface brightness of an O-association is some ten times greater than in the solar vicinity, when observed from other galaxies. This means that stellar associations are the most distinctive features in the outer parts of the Galaxy. Since associations are generally situated within the spiral arms of galaxies, their distribution in our Galaxy gives us the possibility to outline its spiral arms.

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* Multiple systems in which the distances between the components are approximately the same.

Theoretical studies show that associations are dynamically unstable systems and must dissipate. Their «lifetime» is of the order of several million years. This means that stellar associations are young cosmic formations. At the same time associations cannot form as a result of accidenial approaches of separate independent stars. That is why it should be recognized that stars, members of one association, are of common origin and are comparatively young. Their age cannot exceed that of the association itself.

The expansion of associations as a result of their instability was theoretically predicted and confirmed for several O-associations by astronomers of different countries.

Studies of the structure of O-associations have shown that they can possess one or several nuclei in the form of open stellar clusters or multiple stars. The structural and morphological peculiarities of open clusters — the nuclei of O-associations — are closely connected with the physical properties of composing stars. This relationship was taken as the basis for a new classification of open stellar clusters developed at Burakan. The «Atlas of Open Star Clusters of Different Types» published in 1952 clearly illustrates this new classification.

The conclusion that associations are systems of young stars is supported by the fact of their expansion and the presence of unstable multiple systems, of Wolf-Rayet, P Cygni and T Tauri type stars and variable stars of spectral class M with a small amplitude of brightness variation (less than $2^m$) and high luminosity (luminosity class not lower than Ib).

From the study of stellar associations it follows that:

1) Stars in the Galaxy did not form simultaneously and this process is still going on;

2) Stellar associations are the sources of star formation in the Galaxy;

3) Stars in associations originate in groups in the form of multiple stars and stellar clusters and chains.

According to the hypothesis suggested to explain the process of formation of stellar associations, their nuclei are formed as a result of the dissipation of separate protostars, i. e. small and high density bodies of yet unknown nature. This hypothesis agrees with the fact of expansion of stellar associations and does not face any difficulties from the point of view of stellar dynamics.

### The investigation of stars and nebulae

The investigation of stars and nebulae begun in Burakan in 1949 with the 10-inch telescope-spectrograph and a nebular spectrograph were mainly devoted to the study of the continuous stellar spectra in the regions on either side of the Balmer discontinuity. Special attention was given to the spectra of hot giants and super-giants.

The measurements of continuous spectra showed that certain hot stars, generally members of O-associations, have an excess of emission in the ultraviolet region of the spectrum (beyond the Balmer discontinuity) as compared to the normal one. This may be considered as a proof to the instability of such stars and support the above theory of stellar associations.

Detailed spectrophotometric studies of several particularly interesting stars (β Persei, 59 Cygni, ζ Aurigae, AG Draconis etc.) were carried out during recent years.

Among other works those on continuous emission ought to be mentioned. They have lead to new important conclusions about the sources of stellar energy.

The light variations of a number of T Tauri type and unstable stars (UV Ceti type, flare stars, Herbig — Haro objects etc.) in most cases are evidently connected with the presence in their atmosphere of additional sources of emission of a non-thermal character. They intensify the continuous spectrum especially in the shortwaelength region. This additional energy is liberated in the outer layers of the star, but the sources themselves are of interstellar origin.

The main conclusions characterizing the phenomenon of continuous emission can be formulated as follows:

1) The processes of energy liberation observed in the outer layers of unstable stars are not thermonuclear.

2) The process of liberation of large quantities of internal stellar energy in the outer layers of these stars is of a very short duration, the energy being emitted in separate discrete portions.

3) The liberation of internal stellar energy in their atmospheres seems to be connected with the origin of new atomic nuclei that often are unstable and soon disintegrate.

These conclusions are confirmed by observational data on unstable stars received recently in Mexico, the USA and the USSR.

A number of other studies carried out at Burakan are also concerned with stellar physics. The discovery in 1949, independently of the American scientists, of the polarisation of stellar light is of special value.

At the Observatory great attention is paid to the study of diffuse and planetary nebulae. It was revealed that the Orion nebula spectrum changes markedly from its centre to the periphery. These changes were explained by the density difference of dust matter at various distances from the centre of the nebula.

The investigation of a number of other nebulae (M8, M17, MGC 7000) has likewise shown the presence of dust matter, but in smaller amounts than in the Orion nebula.

A strong non-radial polarisation of the emission (reaching 50—60% in certain regions of the nebula) was discovered in the Crab nebula. The polarized emission is mainly connected with the regions of the nebula emitting a continuous spectrum. This excludes the possibility of explaining the emission of the nebula as a result of reflection.

A considerable non-radial polarisation has also been observed in the emission of the IC 432 nebula. Colorimetric studies of the nebula show that it is unusually blue, which also does not support the hypothesis of reflection. In this connection it is necessary to mention that the structure of the nebula IC 432 is close to that of the cometary nebulae, the emission of which contains a non-thermal component (continuous emission).

It follows from the statistical analysis of the distribution of diffuse nebulae that gaseous nebulae (in contrast to the dust nebulae) are of common origin with hot stars. It has been shown that in close vicinity of hot stars the light pressure considerably exceeds the force of attraction. That is why the gaseous matter (mainly hydrogen) moves away from the star. This excludes the very possibility of accretion by stars having surface temperatures higher than 7000° K.

A number of studies were devoted to the dynamics of planetary nebulae. In a resisting interstellar medium the expansion of gaseous envelopes, which are similar to the envelopes of planetary nebulae, novae and Wolf-Rayet type stars must very soon lead to their disintegration. Therefore, outbursts of novae and outflow of matter from Wolf-Rayet stars cannot lead to the formation of planetary nebulae.

According to theoretical calculations, the observed double envelopes of a number of planetary nebulae are not due to the reejection of matter, but are the result of splitting of the main envelope under certain conditions. It is found, moreover, that all planetary nebulae must pass this stage of evolution. This conclusion was taken into consideration when elaborating a new classification of planetary nebulae.

## Radio astrophysics and the study of extragalactic objects

The main problem of radio astrophysics studied at the Observatory is the physical nature of discrete sources of cosmic radio emission. The work is carried on in three directions: the designing and construction of radio telescopes, the elaboration and improvement of observational methods, and the observation of discrete sources of radio emission.

Three interference radio telescopes for the 0.5, 1.5 and 4.2 m radiation have been constructed at the Observatory. The first radio astrophysical observations at Burakan were made by the compensation method. Later the interference and modulation methods were used. Recently the phase-switching method was widely used. It permitted to exclude completely the influence of the galactic background and considerably increased the sensitivity of the radio telescopes. The methods of signal accumulation developed at the Observatory have increased the penetrating power of radio telescopes. The result is that the Burakan radio telescopes of average sizes are able to receive signals from such faint discrete sources which up till now were observed only by the largest radio telescopes in the world.

Systematic observations of the most powerful discrete radio sources allowed to determine their relative emission intensity with a certain degree of precision. The comparison of intensities corresponding to different wavelengths shows that in all studied cases the energy distribution in the radio spectrum is roughly the same, except the Taurus A source. This proves that the emission of all these sources is of the same nature.

The radio emission of the Sun is being observed as well. During the total solar eclipse on June 30, 1954*, the intensity of the solar 1.5 m and 4.2 m radio emission at different phases was studied. The «radio-radius» of the Sun was determined by assuming that the radio brightness was smoothly distributed over the unscreened part of the disc. It appeared to be 1.7 $R_\odot$ and 1.2 $R_\odot$ for the 4.2 m and 1.5 m radiation respectively.

At the present time a large interference radio telescope with cylindrical paraboloid aerials (total area about 5,000 square meters) is under construction. Its elements forming a «Mills cross» will provide great resolving power along both coordinates. The telescope is designed to operate at a wavelength of one meter, but the possibility of working at several wavelengths is provided.

A polarization radio telescope with a solid metal mirror of 12 m in diameter is being designed now. It will have a parallactic mounting and will operate in the centimeter wavelength. The receiving device — a polarization radiometer— and new methods fo measurement will considerably increase the sensitivity to the polarized component of the studied emission. They will also allow to make a complete analysis of the polarization, to increase the accuracy of absolute intensity measurements and the resolving power of the radio telescope, etc.

Studies of discrete radio sources showed that most of them, when identified with optical objects, appeared to be galaxies. Colorimetric and statistical studies of «anomalous» and multiple galaxies are being carried out by means of the 21-21-inch Schmidt camera.

These studies have lead to the conclusion that the components of multiple galaxies have common origin. Among

* At Burakan the phase of the eclipse was 97%.

them predominate the dynamically unstable multiple systems of the Orion Trapezium type*. This testifies that such systems are comparatively young (the time scale in this case differs from that of stars). The same result follows from the analysis of radial velocities of multiple galaxies. It was found that the total energy of multiple galaxies of the Trapezium type, as well as of certain clusters of galaxies, is positive, which means that at present they are expanding systems. Thus we can say that the process of the origin of is still going on in the Universe.

In the light of the above statements a new explanation to the radio emission of colliding galaxies was given. Here evidently the cause of radio emission lies not in the collision of two galaxies but in the process of formation and separation of young galaxies. The extraordinary large sizes and luminosity ($M = -20^m$) of all known «radio galaxies» which cannot be explained by the collision hypothesis support this idea.

This brief outline shows the wide scope of interests of the recently established Observatory and the great prospects for the future extension and development of its astrophysical studies. The construction and mastering in the nearest future of new powerful radio telescopes, the installation of the one-meter Schmidt telescope now under construction, and the application of the most modern methods of electronics and radio engineering will be of great importance for the Observatory.

The construction of new telescopes and the development of new research method will enable the Observatory to extend greatly its scientific activity and to solve the most urgent problems of modern astrophysics.

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* This term means the same as in the case of stellar systems of the Trapezium type.

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